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Effect of Zeolite and Fertilizer Application on Soil Microbial Biomass and Enzyme Activity in Finger Millet

M.N. Shivakumara[1*], R. Krishna murthy[1], C.T. Subbarayappa[1], T.C. Chamegowda[1], M.N. Thimmegowda[2] and R. Muthuraju[3]

[1]Department of Soil Science, Agricultural Chemistry and Agronomist, [2]Agronomist, [3]Department of Agricultural Microbiology, AICRP on Dryland Agriculture, India

**Corresponding author*

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A B S T R A C T

A field experiment was conducted at Zonal Agricultural Research Station, GKVK, Bengaluru during *kharif*-2017-18 to characterize the chemical and physical properties of zeolite and to study its influence on growth and yield of finger millet. Field experiment consists of 20 treatment combinations comprising five levels of zeolite and four levels of graded fertilizers, laid out in RCBD design with factorial concept and replicated thrice on sandy loam soil having slightly acidic soil pH (5.52), electrical conductivity (0.032 dS m^{-1}) and medium organic carbon (0.42%). The dehydrogenase activity recorded higher in the treatment received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) (150.51 µg TPF g^{-1}) in at ear head stage, whereas in post-harvest soil also, same treatment recorded higher dehydrogenase activity (147.65 µg TPF g^{-1}). Urease activity recorded higher in Z_4F_4 (104.91 µg NH_4-N g^{-1}) during ear head stage and post-harvest soils (108.34 µg NH_4-N g^{-1}) also. Acid phosphatase activity was recorded higher in the soil since the pH of soil was acidic and recorded 50.36 µg PNP g^{-1} h^{-1} during ear head stage and their activity decreased at harvest stage (46.66 µg PNP g^{-1} h^{-1}). Microbial biomass carbon (MBC), Microbial biomass nitrogen (MBN) and Microbial biomass phosphorus (MBP) at ear head stage and after harvest of the crop found not significant irrespective of the application of zeolite and fertilizer.

Introduction

Soil enzymes play a critical role in catalyzing reactions leading to organic matter decomposition and serve as bioindicators of biochemical and microbial soil activity. The type of fertilization in plant cultivation affects enzymatic activity and thus the potential viability of plants to grow (Tabatabai, 1994; Wyszkowska *et al.*, 2009). The species and long-term fertilization can result in microbial community shifts in soils (Widmer *et al.*, 2006). Many studies have proved that increasing soil organic matter content by additing organic manures can increase the biological activity in soil (Perez-de-mora and

Madrid, 2007). Applied waste organic materials caused the increase of acidic and alkaline phosphatases activities. According to Casida *et al.,* (1964) dehydrogenases activity is an indicator of soil quality and microbial activity.

However, the interaction between mineral fertilizers, which are currently employed in Polish agriculture and treated with organic matter on soil enzyme activities, is not known. The aim of this investigation was thus to determine the viability of soil treated with both organic matter and fertilizers on various soil enzymes that serve as bioindicators of growth potential of crops.

Zeolites are microporous, aluminosilicate minerals commonly used as commercial adsorbents and catalysts (Yapparov *et al.*, 1988; Mumpton, 1999). Zeolites occur naturally and are also produced synthetically on large scale. Zeolites have been classified on the basis of their morphological characteristics, crystal structure, chemical composition, effective pore diameter, natural occurrence etc.

The unique ion exchange, dehydration–rehydration and adsorption properties of zeolite are the reason for its use in agricultural and aquaculture technologies. Zeolite applications are suitable for water-efficient agricultural uses (Xiubin and Zhanbin, 2001).

Clinoptilolite is the most common natural zeolite used agriculture (Mumpton, 1999; Ramesh *et al.,* 2010). Zeolite contains some macronutrients and micronutrients such as N, K, Ca, Mg, Zn, Mn, and Cu (Navrotsky *et al.*, 1995; Mumpton, 1999). Zeolite has been used on a variety of soil types and a number of crops such as potatoes, maize, rice, tomatoes, eggplant, and carrots, and an increase in the yield of these crops have been observed (Burriesci *et al.*, 1984; Yapparov *et al.,* 1988).

The objective of this study was to quantify the influence of application of inorganic fertilizer (NPK) along with zeolite on soil microbial communities and activities of representative soil enzymes below vegetation of finger millet.

Materials and Methods

Site and experimental details

A field experiment was conducted during *Kharif,* 2017 at the Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru.

The soil of the experimental site was sandy clay loam in texture, acidic pH (5.52), electrical conductivity (0.032 dS m^{-1}), medium organic carbon (4.2 g kg^{-1}), available nitrogen, phosphorus and potassium contents of the soil were 258.29, 194.28 and 197.48 kg ha^{-1}, respectively. The exchangeable calcium and magnesium content were 1.85 and 0.72 cmol (p^{+}) kg^{-1}, respectively. the micronutrients like iron, manganese, copper and zinc content of soil were 12.46, 16.72, 0.82 and 1.56 mg kg,$^{-1}$ respectively.

The experiment consists of 5 different levels of zeolite (0, 20, 30, 40 and 50 kg ha^{-1}) and 4 different levels of fertilizer NPK (50, 75, 100 and 125% RDF) were tried in factorial RCBD with 3 replications. Finger millet (GPU-28) was taken up as a test crop and recommended dose of fertilizer is 50: 40: 37.5 kg of N, P_2O_5 and K_2O per ha.

Calculated quantities of nitrogen, phosphorus and potassium were applied treatment wise, in the form of urea, SSP and muriate of potash respectively. Nitrogen was applied in two split doses, that is 50 per cent nitrogen at initial and another 50 per cent at tillering stage, whereas P_2O_5 and K_2O was applied as basal dose.

Zeolite was applied along with fertilizers initially.

Treatment details

Zeolite levels (Z)

Z_0 : Control

Z_1 : Zeolite @ 20 kg ha^{-1}

Z_2 :Zeolite @ 30 kg ha^{-1}

Z_3 :Zeolite @ 40 kg ha^{-1}

Z_4 : Zeolite @ 50 kg ha^{-1}

Fertilizer levels (F)

F_1: 50% RDF

F_2: 75% RDF

F_3: 100% RDF

F_4: 125% RDF

Treatment combinations (Z×F)

T_1: Z_0F_1: Control + 50% RDF

T_2: Z_0F_2: Control + 75% RDF

T_3: Z_0F_3: Control + 100% RDF

T_4: Z_0F_4: Control + 125% RDF

T_5: Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF

T_6: Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF

T_7: Z_1F_3: Zeolite @ 20 kg ha^{-1}+100% RDF

T_8: Z_1F_4: Zeolite @ 20 kg ha^{-1}+125% RDF

T_9: Z_2F_1: Zeolite @ 30 kg ha^{-1}+ 50%RDF

T_{10}: Z_2 F_2:Zeolite @ 30 kg ha^{-1}+ 75% RDF

T_{11}: Z_2F_3: Zeolite @ 30 kg ha^{-1}+ 100% RDF

T_{12}: Z_2F_4: Zeolite @ 30 kg ha^{-1}+ 125% RDF

T_{13}: Z_3F_1: Zeolite @ 40 kg ha^{-1}+ 50% RDF

T_{14}: Z_3F_2: Zeolite @ 40 kg ha^{-1}+ 75% RDF

T_{15}: Z_3F_3: Zeolite @ 40 kg ha^{-1}+ 100% RDF

T_{16}: Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF

T_{17}: Z_4F_1: Zeolite @ 50 kg ha^{-1}+ 50% RDF

T_{18}: Z_4F_2: Zeolite @ 50 kg ha^{-1}+ 75% RDF

T_{19}: Z_4F_3: Zeolite @ 50 kg ha^{-1}+ 100% RDF

T_{20}: Z_4F_4: Zeolite @ 50 kg ha^{-1}+ 125% RDF

Dehydrogenase activity

Determination of dehydrogenase activity was carried out by adopting the methodology given by Casida *et al.,* (1964). It is based on the principle that 2,3,5-triphenyl tetrazolium chloride (TTC), used as electron acceptor in place of O_2, is reduced to triphenyl formazon (TPF), which imparts colour. The quantity of TPF formed was measured by spectrophotometer at 485 nm wavelength and expressed as µg of TPF formed g^{-1} soil h^{-1}.

Urease activity

The urease activity was determined by adopting the procedure given by Tabatabai and Bremner (1972). It involves the determination of ammonia released by urease activity when soil is incubated with tris (hydroxymethyl) amino methane (THAM) buffer, urea solution and toluene at 37°C for 2 hr, ammonia released being determined by a rapid procedure involving treatment of the incubated soil sample with 2.5M KCL containing a urease inhibitor (Ag_2SO_4).

Phosphatase activity

The phosphatase activity was determined by adopting the procedure given by Tabatabai and Bremner (1969). In this method, p-nitrophenol phosphate (PNP-P) was used as a substrate and the hydrolyzed p-nitrophenol (PNP) was measured. The produced PNP in the soil was extracted and quantified to assess the phosphatase activity. The activity was expressed as µg of PNP-P hydrolyzed g^{-1} soil h^{-1} at 37 ± 20°C.

Soil microbial biomass C and N

Soil microbial biomass was estimated following the fumigation and extraction method as proposed by Carter (1991). Ninhydrin-reactive N released during the fumigation of soil was determined by using ninhydrin reagent and was used as a measure of microbial biomass. For this, each soil sample was divided in to two sets. One set of moist soil sample (10 g soil on oven dry basis) was fumigated with ethanol-free chloroform for 5 days in screw-capped bottles. Then the screw caps were removed and kept in an oven at 40°C for overnight to remove the chloroform and extracted with 2M KCl by placing these bottles on a reciprocal shaker for min. The suspension was filtered using Whatman No.1 filter paper. In a similar manner unfumigated soil sample was also extracted. To a known aliquot of soil extract, 4 mL of freshly prepared ninhydrin reagent was added and the mixture was boiled in water bath for 20 min. The contents were allowed to cool and the volume was made up to 10 ml using 1:1 mixture of methoxy ethanol and distilled water. The intensity of purple colour developed was recorded using spectrophotometer at 570 nm wave length. A standard curve was developed using five different concentration of L-Leucine –N (3.5 to 16.8 µg N mL^{-1}) dissolved in 2M KCl. Absorbance value were compared with a standard curve and the microbial biomass C and N were calculated using the formula.

Biomass C g $soil^{-1}$

$$\frac{\text{Ninhydrin reactive-N in fumigated soil} - \text{Ninhydrin reactive-N in unfumigated soil}}{\text{Weight of soil sample}} \times 24$$

Biomass N g $soil^{-1}$

$$\frac{\text{Ninhydrin reactive-N in fumigated soil} - \text{Ninhydrin reactive-N in unfumigated soil}}{\text{Weight of soil sample}} \times 2.8$$

Soil microbial biomass P

For the determination of soil microbial biomass phosphorus (SMB-P), ten gram soil sample (oven dry basis) was shaken with 200 mL 0.5 M $NaHCO_3$ in 250 mL conical flasks for 30 minutes at 25°C and 150 rpm in an orbital shaker (Brookes *et al.,* 1982). SMB-P was determined in both fumigated and non-fumigated soil samples under similar set of conditions and values were measured at 660 nm wavelength using ascorbic acid method (Olsen *et al.,* 1954).

Results and Discussion

Dehydrogenase activity at earhead stage and after harvest of the crop

Data pertaining to dehydrogenase activity and urease activity of soil at earhead stage and after harvest of crop as influenced by application of different levels of fertilizer and zeolite has been presented in Table. 1.

The application of zeolite at different levels showed significant differences in dehydrogenase activity at earhead stage and after harvest of the crop. At earhead stage of the crop, the dehydrogenase activity varied from 118.60 µg TPF g^{-1} soil h^{-1} (Z_0) to 141.29 µg TPF g^{-1} soil h^{-1} (Z_4) in second season. The treatment received 50 kg ha^{-1}zeolite (Z_4) recorded significantly higher dehydrogenase activity (134.28 µg TPF g^{-1} soil h^{-1}, 141.29 µg TPF g^{-1} soil h^{-1} and 137.79 µg TPF g^{-1} soil h^{-1}) compared to rest of the treatments during first, second season and pooled data, respectively. In post-harvest soil, the dehydrogenase activity varies from 115.30 µg TPF g^{-1} soil h^{-1} (Z_0) to 137.34 µg TPF g^{-1} soil h^{-1} (Z_4) during second season. The treatment received 50 kg ha^{-1}zeolite (Z_4) recorded significantly higher dehydrogenase activity (130.2 µg TPF g^{-1} soil h^{-1}, 137.34 µg TPF g^{-1} soil h^{-1} and 133.88 µg TPF g^{-1} soil h^{-1}) compared to rest of the treatments during first, second season and pooled data, respectively.

Fertilizer application significantly influenced the dehydrogenase activity at earhead stage after harvest of the crop. At earhead stage of the crop, significantly higher dehydrogenase activity was recorded in treatment which received 125 per cent RDF (F_4) (141.69 µg TPF g^{-1} soil h^{-1}, 145.12 µg TPF g^{-1} soil h^{-1} and 143.40 µg TPF g^{-1} soil h^{-1}) followed by 100 per cent RDF (F_3) (133.90 µg TPF g^{-1} soil h^{-1}, 135.18 µg TPF g^{-1} soil h^{-1} and 134.54 µg TPF g^{-1} soil h^{-1}) during first, second season and pooled analysis, respectively. Whereas, lower dehydrogenase activity was recorded in treatment which received 50 per cent RDF (114.60 µg TPF g^{-1} soil h^{-1}, 117.24 µg TPF g^{-1} soil h^{-1} and 116.42 µg TPF g^{-1} soil h^{-1}) during first, second season and pooled analysis, respectively. In post-harvest soil, significantly higher dehydrogenase activity was recorded in treatment which received 125 per cent RDF (F_4) (137.39 µg TPF g^{-1} soil h^{-1}, 140.60 µg TPF g^{-1} soil h^{-1} and 138.99 µg TPF g^{-1} soil h^{-1}) followed by 100 per cent RDF (F_3) (128.14 µg TPF g^{-1} soil h^{-1}, 130.74 µg TPF g^{-1} soil h^{-1} and 129.44 µg TPF g^{-1} soil h^{-1}) in first, second season and pooled analysis, respectively. Whereas, lower dehydrogenase activity was recorded in treatment which received 50 per cent RDF (108.82 µg TPF g^{-1} soil h^{-1}, 114.35 µg TPF g^{-1} soil h^{-1} and 111.58 µg TPF g^{-1} soil h^{-1}) in first, second season and pooled analysis, respectively.

Significant difference in dehydrogenase activity was observed due to interaction of zeolite and fertilizer levels at earhead stage of the crop. In first, second season and pooled analysis, significantly higher dehydrogenase activity was recorded in the treatment received zeolite @ 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) (147.20 µg TPF g^{-1} soil h^{-1}, 153.81 µg TPF g^{-1} soil h^{-1} and 150.51 µg TPF g^{-1} soil h^{-1} respectively) followed by treatment $Z_4F_{3:}$ zeolite @ 50 kg ha^{-1}+100 per cent RDF (142.81 µg TPF g^{-1} soil h^{-1}, 146.30 µg TPF g^{-1} soil h^{-1} and 144.56 µg TPF g^{-1} soil h^{-1} respectively) when compared to the control which received no zeolite and 50 per cent RDF (Z_0F_1) (103.08 µg TPF g^{-1} soil h^{-1}, 109.29 µg TPF g^{-1} soil h^{-1} and 103.69 µg TPF g^{-1} soil h^{-1} respectively). After harvest of the crop in first, second season and pooled analysis, significantly higher dehydrogenase activity was recorded in the treatment received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) (145.45 µg TPF g^{-1} soil h^{-1}, 149.85 µg TPF g^{-1} soil h^{-1} and 147.65 µg TPF g^{-1} soil h^{-1} respectively) followed by treatment received zeolite 40 kg ha^{-1}+125 per cent RDF (Z_3F_4) (141.48 µg TPF g^{-1} soil h^{-1}, 146.59 µg TPF g^{-1} soil h^{-1} and 144.04 µg TPF g^{-1} soil h^{-1} respectively) when compared to the control which received 50 per cent RDF without zeolite (Z_0F_1) (97.08 µg TPF g^{-1} soil h^{-1}, 102.54 µg TPF g^{-1} soil h^{-1} and 99.81 µg TPF g^{-1} soil h^{-1} respectively).

The dehydrogenase activity gives an indication of total microbial activity (Amanda Shylla, 2012). Higher dehydrogenase activity was recorded in zeolite and fertilizer treated plots than in control might be due to increased microbial activity as a result of increased availability of substrate (organic carbon) in FYM and zeolite will keeps the nutrients for long period so that the nutrients required for their multiplication and development will be sufficiently larger. Dehydrogenase activity was very less in control or plots which received less zeolite and fertilizers. Application of balanced nutrients at higher level in combination with zeolite improved the nutrient status of soil which in turn enhanced dehydrogenase activity (Ajay *et al.*, 2017). The population of soil microbes was triggered by the addition of organic manures as FYM with inorganic fertilizers enhanced the availability of nitrogen and zinc which are synergistic in nature and ultimately increased the dehydrogenase activity in soil. Similar findings were reported by and Sriramachandrasekharan and Mathan (1997).

Urease activity at earhead stage and after harvest of the crop

Data pertaining to urease activity of soil at earhead stage as influenced by application of different levels of fertilizer and zeolite has been presented in Table 1.

At earhead stage the urease activity significantly higher in treatment received 50 kg ha^{-1} zeolite (Z_4) i.e. 97.23 µg NH_4-N g^{-1} soil $h^{-1,}$ 99.90 µg NH_4-N g^{-1} soil h^{-1} and 98.57 µg NH_4-N g^{-1} soil h^{-1} when compared to control which received no zeolite (Z_0) i.e. 90.23 µg NH_4-N g^{-1} soil $h^{-1,}$ 94.17 µg NH_4-N g^{-1} soil h^{-1} and 92.20 µg NH_4-N g^{-1} soil h^{-1} in first, second season and pooled data, respectively. At post-harvest soil the urease activity significantly higher in treatment received 50 kg ha^{-1} zeolite (Z_4), 100.63 µg NH_4-N g^{-1} soil $h^{-1,}$ 104.00 µg NH_4-N g^{-1} soil h^{-1} and 102.32 µg NH_4-N g^{-1} soil h^{-1} when compared to control which received no zeolite (Z_0), 93.21µg NH_4-N g^{-1} soil $h^{-1,}$ 98.15 µg NH_4-N g^{-1} soil h^{-1} and 95.68 µg NH_4-N g^{-1} soil h^{-1} during first, second season and pooled data, respectively.

Fertilizer application significantly influenced the urease activity at earhead stage of the crop. Significantly higher urease activity was recorded in treatment F_4 (125% RDF) 100.91 µg NH_4-N g^{-1} soil $h^{-1,}$ 102.79 µg NH_4-N g^{-1} soil h^{-1} and 101.85 µg NH_4-N g^{-1} soil h^{-1} during first, second season and pooled data, respectively followed by treatment F_3 (100% RDF) (96.71 µg NH_4-N g^{-1} soil $h^{-1,}$ 99.32 µg NH_4-N g^{-1} soil h^{-1} and 98.02 µg NH_4-N g^{-1} soil h^{-1}), The lower urease activity was recorded in the treatment which received 50 per cent RDF (F_1) (85.65µg NH_4-N g^{-1} soil $h^{-1,}$ 89.03 µg NH_4-N g^{-1} soil h^{-1} and 87.34 µg NH_4-N g^{-1} soil h^{-1}) during first, second season and pooled data, respectively. In post-harvest soil, significantly higher urease activity was recorded in treatment F_4 (125% RDF), 104.02 µg NH_4-N g^{-1} soil $h^{-1,}$ 106.77 µg NH_4-N g^{-1} soil h^{-1} and 105.39 µg NH_4-N g^{-1} soil h^{-1} during first, second season and pooled data, respectively followed by treatment F_3 (100% RDF), 99.73 µg NH_4-N g^{-1} soil $h^{-1,}$ 103.52 µg NH_4-N g^{-1} soil h^{-1} and 101.63 µg NH_4-N g^{-1} soil h^{-1}), The lower urease activity was recorded in the treatment which received 50 per cent RDF (F_1) (88.67 µg NH_4-N g^{-1} soil h^{-1}, 93.16 µg NH_4-N g^{-1} soil h^{-1} and 90.91 µg NH_4-N g^{-1} soil h^{-1}) during first, second season and pooled data, respectively.

Pooled analysis of two years (2017 and 2018) of experimental data at earhead stage of the crop revealed significant difference in urease activity was observed due to interaction of zeolite and fertilizer levels. The treatment which received zeolite @ 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) showed higher urease activity (104.23 µg NH_4-N g^{-1} soil h^{-1}, 105.59 µg NH_4-N g^{-1} soil h^{-1} and 104.91 µg NH_4-N g^{-1} soil h^{-1}) followed by treatment received zeolite @ 50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (100.26 µg NH_4-N g^{-1} soil $h^{-1,}$ 101.63µg NH_4-N g^{-1} soil h^{-1} and 100.94 µg NH_4-N g^{-1} soil h^{-1}) in first, second season and pooled data, respectively. Whereas, lower urease activity was recorded in the treatment which received 50 per cent RDF with no zeolite (Z_0F_1) (82.39, 86.33 and 84.36 µg NH_4-N g^{-1} soil h^{-1} in first season).

Pooled analysis of two years (2017 and 2018) of experimental data of post-harvest soil also revealed significant difference in urease activity due to interaction of zeolite and fertilizer levels with higher urease activity in Z_4F_4 (107.63, 109.06 and 108.34 µg NH_4-N g^{-1} soil h^{-1} in 2017, 2018 and pooled, respectively).

The activity of urease, the enzyme that catalyzes the hydrolysis of urea and which is widely used in the evaluation of changes in soil quality for soil management (Díaz-Marcote and Polo, 1995), increased with the application of zeolite (Table 1). The lower urease activity was found in the control treatment. Higher urease enzyme activity was recorded with the application of zeolite and it is attributed to the N fixing capacity of zeolite by its microspores increased the urease activity in soil. Perucci (1990) reported that an increase in urease activity when soil is amended with zeolite, recommended fertilizer and FYM. These results are in line with the findings of Chakrabarti *et al.,* (2000) and Amanda Shylla (2012) who recorded increased urease activity on addition of hydrogel with chemical fertilizers. Higher N content in soil stimulated heterotrophic microbial activity and resulted in higher activity of hydrolytic enzymes in turn, urease activity was enhanced (Dilly *et al.*, 2007).

Acid phosphatase activity at earhead stage and after harvest of the crop

Data pertaining to acid phosphatase activity of soil as influenced by application of different levels of fertilizer and zeolite have been presented in Table 2.

Application of zeolite at different levels showed significant differences in acid phosphatise activity at earhead stage and after harvest of the crop. Significantly higher acid phosphatise activity was recorded in the treatment Z_4 which received 50 kg ha^{-1} zeolite (42.76 µg PNP g^{-1} h^{-1}, 47.13 µg PNP g^{-1} h^{-1} and 44.95 µg PNP g^{-1} h^{-1}) followed by Z_3 which received 40 kg ha^{-1} zeolite (40.85 µg PNP g^{-1} h^{-1}, 45.32 µg PNP g^{-1} h^{-1} and 43.09 µg PNP g^{-1} h^{-1}) during first, second season and pooled data, respectively, over the control (33.56 µg PNP g^{-1} h^{-1}, 37.42 µg PNP g^{-1} h^{-1} and 35.49 µg PNP g^{-1} h^{-1}). In post-harvest soil significantly higher acid phosphatise activity was recorded in the treatment Z_4 which received 50 kg ha^{-1} zeolite (39.19 µg PNP g^{-1} h^{-1}, 43.29 µg PNP g^{-1} h^{-1} and 41.24 µg PNP g^{-1} h^{-1}) followed by Z_3 which received 40 kg ha^{-1} zeolite (36.99 µg PNP g^{-1} h^{-1}, 41.14 µg PNP g^{-1} h^{-1} and 39.06 µg PNP g^{-1} h^{-1}) during first, second season and pooled data, respectively, over the control (30.60 µg PNP g^{-1} h^{-1}, 34.38 µg PNP g^{-1} h^{-1} and 32.49 µg PNP g^{-1} h^{-1}).

Pooled data of two years (2017 and 2018) revealed that among fertilizer treatments acid phosphatase activity progressively increased with increase in the level of fertilizers from 50 to 125% at earhead stage of the crop. Significantly higher acid phosphatise activity was recorded in treatment F_4 (125% RDF) 44.35 µg PNP g^{-1} h^{-1}, 48.34 µg PNP g^{-1} h^{-1} and 46.35 µg PNP g^{-1} h^{-1}in first, second season and pooled data, respectively over the other treatments.

Lower acid phosphatise activity was recorded in treatment F_1 (50% RDF) 30.31 µg PNP g^{-1} h^{-1}, 34.79 µg PNP g^{-1} h^{-1} and 32.55 µg PNP g^{-1} h^{-1} in first, second season and pooled data, respectively. Pooled analysis of two years (2017 and 2018) of experimental data revealed that among fertilizer treatments acid phosphatise activity progressively increased with increase in the level of fertilizers from 50 to 125% at post-harvest soils. Significantly higher acid phosphatase activity was recorded in treatment F_4 (125% RDF) 40.71 µg PNP g^{-1} h^{-1}, 45.03 µg PNP g^{-1} h^{-1} and 42.87 µg PNP g^{-1} h^{-1} during first, second season and pooled data, respectively over the other treatments. Lower acid phosphatise activity was recorded in treatment F_1 (50% RDF) 27.07 µg PNP g^{-1} h^{-1}, 31.09 µg PNP g^{-1} h^{-1} and 29.08 µg PNP g^{-1} h^{-1} in first, second season and pooled data, respectively. Significant difference in acid phosphatise activity was observed due to interaction of zeolite and fertilizer levels at earhead stage and after harvest of the crop. In first, second season and pooled analysis, significantly higher acid phosphatase activity was recorded in the treatment received zeolite @ 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) (48.08 µg PNP g^{-1} h^{-1}, 52.63 µg PNP g^{-1} h^{-1} and 50.36 µg PNP g^{-1} h^{-1} respectively) followed by treatment received zeolite @ 40 kg ha^{-1} +125 per cent RDF (Z_3F_4) (46.01 µg PNP g^{-1} h^{-1}, 50.94 µg PNP g^{-1} h^{-1} and 48.48 µg PNP g^{-1} h^{-1}respectively) when compared to the control which received 50 per cent RDF (Z_0F_1) with no zeolite (26.48 µg PNP g^{-1} h^{-1}, 30.49 µg PNP g^{-1} h^{-1} and 28.48 µg PNP g^{-1} h^{-1}). Significant difference in acid phosphatise activity was observed due to interaction of zeolite and fertilizer levels in post-harvest soils. In first, second season and pooled analysis, significantly higher acid phosphatise activity was recorded in the treatment received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) (44.22 µg PNP g^{-1} h^{-1}, 49.11 µg PNP g^{-1} h^{-1} and 46.66 µg PNP g^{-1} h^{-1} respectively) followed by treatment received zeolite 40 kg ha^{-1}+125 per cent RDF (Z_3F_4) (42.32 µg PNP g^{-1} h^{-1}, 46.56 µg PNP g^{-1} h^{-1} and 44.44 µg PNP g^{-1} h^{-1} respectively) when compared to the control which received 50 per cent RDF (Z_0F_1) without zeolite (23.34 µg PNP g^{-1} h^{-1}, 27.12 µg PNP g^{-1} h^{-1} and 25.23 µg PNP g^{-1} h^{-1}). Soil pH was acidic, the acid phosphatase activity found higher in the present study in both (2017 and 2018) the season. Chemical fertilizers suppressed the acid and alkaline phosphatase activity which can be explained through considering the fact that phosphatase synthesis is inhibited by available phosphorus (Wang *et al.*, 2012). This phosphatase activity found higher in the treatment received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) and zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4), this might be due to harmless nature of zeolite to the microbial load intern nutrient application leads to the sufficient nutrient supply to microbes for their growth and development. Application of FYM as recommended in the package of practice also contributed for the development of microbes. This increase in activity may be due to the release of more organically bound P due to faster decomposition of organic matter in presence of mineral N and P which stimulate the synthesis of the enzyme (Mohammadi *et al.,* 2012). The conversion of organic P into inorganic P was mainly brought about and governed by phosphatase activity. Further, it is dependent on pH, organic matter and available P status of the soil.

Table.1 Dehydrogenase and urease activity in soil on ear head and at harvest stage of finger millet as influenced by different levels of zeolite and fertilizer application

Treatments	Dehydrogenase (µg TPF g^{-1} soil h^{-1}) At earhead stage			Dehydrogenase (µg TPF g^{-1} soil h^{-1}) Post-harvest soil			Urease (µg NH_4-N g^{-1} soil h^{-1}) At earhead stage			Urease (µg NH_4-N g^{-1} soil h^{-1}) Post-harvest soil		
	2017	2018	pooled	2017	2018	pooled	2017	2018	pooled	2017	2018	pooled
Zeolite levels												
Z_0 : Control	116.30	118.60	117.45	111.28	115.30	113.29	90.23	94.17	92.20	93.21	98.15	95.68
Z_1 : Zeolite @ 20 kg ha^{-1}	128.81	126.46	127.64	122.73	123.30	123.01	91.65	94.49	93.07	94.53	98.99	96.76
Z_2 : Zeolite @ 30 kg ha^{-1}	132.12	133.57	132.84	125.31	128.26	126.78	93.91	95.46	94.68	97.18	99.61	98.40
Z_3 : Zeolite @ 40 kg ha^{-1}	131.05	135.88	133.97	126.08	131.91	128.99	95.46	98.20	96.83	98.44	102.39	100.41
Z_4 : Zeolite @ 50 kg ha^{-1}	134.28	141.29	137.79	130.42	137.34	133.88	97.23	99.90	98.57	100.63	104.00	102.32
S.Em±	**0.62**	**0.47**	**0.46**	**0.60**	**0.46**	**0.42**	**0.35**	**0.33**	**0.32**	**0.34**	**0.33**	**0.32**
CD (P=0.05)	**1.77**	**1.36**	**1.32**	**1.71**	**1.33**	**1.21**	**0.99**	**0.95**	**0.92**	**0.99**	**0.94**	**0.92**
Fertilizer levels												
F_1: 50% RDF	114.60	117.24	116.42	108.82	114.35	111.58	85.65	89.03	87.34	88.67	93.16	90.91
F_2: 75% RDF	123.86	126.90	125.38	118.30	123.19	120.74	91.52	94.63	93.08	94.78	99.07	96.92
F_3: 100% RDF	133.90	135.18	134.54	128.14	130.74	129.44	96.71	99.32	98.02	99.73	103.52	101.63
F_4: 125% RDF	141.69	145.12	143.40	137.39	140.60	138.99	100.91	102.79	101.85	104.02	106.77	105.39
S.Em±	**0.55**	**0.42**	**0.41**	**0.53**	**0.41**	**0.38**	**0.31**	**0.30**	**0.29**	**0.31**	**0.29**	**0.29**
CD (P=0.05)	**1.59**	**1.21**	**1.18**	**1.53**	**1.19**	**1.08**	**0.89**	**0.85**	**0.82**	**0.88**	**0.84**	**0.83**
Zeolite levels X Fertilizer levels												
Z_0F_1: Control + 50% RDF	103.08	109.29	103.69	97.08	102.54	99.81	82.39	86.33	84.36	85.57	90.31	87.94
Z_0F_2: Control + 75% RDF	109.21	114.76	111.98	104.08	111.59	107.84	88.50	92.44	90.47	91.68	96.42	94.05
Z_0F_3: Control + 100% RDF	120.99	121.54	121.27	116.26	116.65	116.46	92.86	96.79	94.83	96.04	100.77	98.40
Z_0F_4: Control + 125% RDF	131.93	133.81	132.87	127.71	130.41	129.06	97.19	101.12	99.16	99.57	105.10	102.33
Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF	114.25	113.88	114.06	110.02	110.48	110.25	83.95	87.31	85.63	86.33	91.44	88.88
Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF	126.33	119.87	123.10	120.54	118.78	119.66	88.71	91.34	90.02	92.31	96.97	94.64
Z_1F_3: Zeolite @ 20 kg ha^{-1} +100% RDF	133.80	129.53	131.66	126.64	126.58	126.61	94.95	97.93	96.44	97.33	102.06	99.69
Z_1F_4: Zeolite @ 20 kg ha^{-1} +125% RDF	140.87	142.56	141.72	133.71	137.36	135.54	98.99	101.37	100.18	102.15	105.49	103.82
Z_2F_1: Zeolite @ 30 kg ha^{-1} + 50%RDF	117.22	122.61	119.92	110.06	117.21	113.64	85.59	87.41	86.50	88.74	91.57	90.16
Z_2F_2:Zeolite @ 30 kg ha^{-1} + 75% RDF	130.56	130.57	130.57	123.40	125.17	124.29	91.42	93.47	92.45	94.57	97.63	96.10
Z_2F_3:Zeolite @ 30 kg ha^{-1} + 100% RDF	136.35	137.24	136.80	129.19	131.85	130.52	97.24	98.61	97.93	100.40	102.77	101.58
Z_2F_4:Zeolite @ 30 kg ha^{-1} + 125%	144.34	143.85	144.10	138.58	138.81	138.69	101.40	102.33	101.87	105.00	106.49	105.75

RDF												
Z_3F_1: Zeolite @ 40 kg ha^{-1} + 50% RDF	118.70	124.88	121.79	112.94	119.90	116.42	87.20	90.59	88.90	90.17	94.75	92.46
Z_3F_2: Zeolite @ 40 kg ha^{-1} + 75% RDF	125.87	129.82	127.84	120.11	124.84	122.48	93.64	97.04	95.34	96.62	101.24	98.93
Z_3F_3: Zeolite @ 40 kg ha^{-1} + 100% RDF	135.54	141.26	138.40	129.78	136.28	133.03	98.26	101.66	99.96	101.24	105.86	103.55
Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF	144.09	151.57	147.83	141.48	146.59	144.04	102.76	103.51	103.13	105.73	107.71	106.72
Z_4F_1: Zeolite @ 50 kg ha^{-1} + 50% RDF	119.76	125.56	122.66	114.00	121.61	117.80	89.11	93.51	91.31	92.51	97.71	95.11
Z_4F_2: Zeolite @ 50 kg ha^{-1} + 75% RDF	127.33	139.50	133.42	123.37	135.55	129.46	95.33	98.88	97.10	98.73	103.07	100.90
Z_4F_3: Zeolite @ 50 kg ha^{-1} + 100% RDF	142.81	146.30	144.56	138.85	142.35	140.60	100.26	101.63	100.94	103.66	106.16	104.91
Z_4F_4: Zeolite @ 50 kg ha^{-1} + 125% RDF	147.20	153.81	150.51	145.45	149.85	147.65	104.23	105.59	104.91	107.63	109.06	108.34
S.Em±	**1.24**	**0.95**	**0.92**	**1.19**	**0.93**	**0.85**	**0.69**	**0.66**	**0.64**	**0.69**	**0.66**	**0.65**
CD (P=0.05)	**3.55**	**2.72**	**2.63**	**3.41**	**2.65**	**2.42**	**2.09**	**1.93**	**1.90**	**2.09**	**1.98**	**1.95**

Table.2 Acid and alkaline phosphatase activity in soil at ear head and harvest stage of finger millet as influenced by different levels of zeolite and fertilizer application

Treatments	Acid phosphatase (µg PNP g^{-1} h^{-1}) At earhead stage			Acid phosphatase (µg PNP g^{-1} h^{-1}) Post-harvest soil			Alkaline Phosphatase (µg PNP g^{-1} h^{-1}) At earhead stage			Alkaline Phosphatase (µg PNP g^{-1} h^{-1}) Post-harvest soil		
	2017	**2018**	**pooled**	**2017**	**2018**	**pooled**	**2017**	**2018**	**pooled**	**2017**	**2018**	**pooled**
Zeolite levels												
Z_0 : Control	33.56	37.42	35.49	30.60	34.38	32.49	15.42	16.00	15.71	17.40	18.16	17.78
Z_1 : Zeolite @ 20 kg ha^{-1}	35.23	39.66	37.45	31.91	36.17	34.04	16.07	16.70	16.38	17.86	18.88	18.37
Z_2 : Zeolite @ 30 kg ha^{-1}	37.88	42.53	40.20	34.26	38.66	36.46	17.31	18.04	17.67	19.28	20.25	19.76
Z_3 : Zeolite @ 40 kg ha^{-1}	40.85	45.32	43.09	36.99	41.14	39.06	18.11	18.90	18.50	20.08	21.20	20.64
Z_4 : Zeolite @ 50 kg ha^{-1}	42.76	47.13	44.95	39.19	43.29	41.24	19.77	20.51	20.14	21.93	22.88	22.40
S.Em±	**0.23**	**0.25**	**0.22**	**0.26**	**0.23**	**0.24**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**	**0.23**
CD (P=0.05)	**0.66**	**0.71**	**0.63**	**0.75**	**0.66**	**0.70**	**0.65**	**0.65**	**0.65**	**0.65**	**0.65**	**0.65**
Fertilizer levels												
F_1: 50% RDF	30.31	34.79	32.55	27.07	31.09	29.08	15.23	15.92	15.57	17.20	18.13	17.67
F_2: 75% RDF	37.13	41.32	39.22	33.61	37.63	35.62	16.62	17.32	16.97	18.60	19.57	19.08
F_3: 100% RDF	40.45	45.19	42.82	36.97	41.17	39.07	18.32	19.01	18.67	20.30	21.27	20.78
F_4: 125% RDF	44.35	48.34	46.35	40.71	45.03	42.87	19.17	19.87	19.52	21.15	22.12	21.63
S.Em±	**0.21**	**0.22**	**0.20**	**0.24**	**0.21**	**0.22**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**	**0.20**
CD (P=0.05)	**0.59**	**0.64**	**0.56**	**0.67**	**0.59**	**0.62**	**0.58**	**0.58**	**0.58**	**0.58**	**0.58**	**0.58**
Zeolite levels X Fertilizer levels												
Z_0F_1: Control + 50% RDF	26.48	30.49	28.48	23.34	27.12	25.23	13.82	14.40	14.11	15.80	16.55	16.18
Z_0F_2: Control + 75% RDF	31.88	35.89	33.88	28.74	32.52	30.63	15.14	15.72	15.43	17.12	17.87	17.50
Z_0F_3: Control + 100% RDF	35.11	39.13	37.12	31.98	35.75	33.86	16.19	16.76	16.48	18.16	18.92	18.54
Z_0F_4: Control + 125% RDF	40.75	44.18	42.47	38.35	42.13	40.24	16.54	17.12	16.83	18.52	19.27	18.90
Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF	28.01	32.93	30.47	25.78	29.55	27.66	14.42	15.06	14.74	16.22	17.21	16.72
Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF	34.21	38.51	36.36	31.19	34.96	33.07	15.20	15.83	15.52	17.00	18.03	17.51

Z_1F_3: Zeolite @ 20 kg ha^{-1} +100% RDF	36.58	42.25	39.41	33.19	38.07	35.63	16.78	17.41	17.09	18.57	19.60	19.09
Z_1F_4: Zeolite @ 20 kg ha^{-1} +125% RDF	42.14	44.94	43.54	37.49	42.11	39.80	17.87	18.50	18.19	19.67	20.70	20.18
Z_2F_1: Zeolite @ 30 kg ha^{-1} + 50%RDF	29.49	35.20	32.35	26.56	31.02	28.79	15.65	16.38	16.01	17.62	18.57	18.10
Z_2F_2:Zeolite @ 30 kg ha^{-1} + 75% RDF	35.89	39.62	37.76	31.68	36.31	33.99	16.26	16.99	16.62	18.23	19.21	18.72
Z_2F_3:Zeolite @ 30 kg ha^{-1} + 100% RDF	41.37	46.28	43.82	37.64	42.10	39.87	18.22	18.96	18.59	20.20	21.17	20.69
Z_2F_4:Zeolite @ 30 kg ha^{-1} + 125% RDF	44.76	49.02	46.89	41.18	45.22	43.20	19.09	19.83	19.46	21.07	22.04	21.56
Z_3F_1: Zeolite @ 40 kg ha^{-1} + 50% RDF	32.72	37.12	34.92	28.47	32.74	30.60	15.68	16.47	16.07	17.65	18.69	18.17
Z_3F_2: Zeolite @ 40 kg ha^{-1} + 75% RDF	41.09	45.49	43.29	36.98	41.11	39.04	17.38	18.17	17.78	19.36	20.51	19.93
Z_3F_3: Zeolite @ 40 kg ha^{-1} + 100% RDF	43.59	47.74	45.67	40.18	44.16	42.17	18.99	19.78	19.38	20.96	22.11	21.54
Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF	46.01	50.94	48.48	42.32	46.56	44.44	20.38	21.17	20.78	22.36	23.51	22.93
Z_4F_1: Zeolite @ 50 kg ha^{-1} + 50% RDF	34.84	38.22	36.53	31.23	35.01	33.12	16.56	17.30	16.93	18.72	19.64	19.18
Z_4F_2: Zeolite @ 50 kg ha^{-1} + 75% RDF	42.56	47.10	44.83	39.47	43.25	41.36	19.13	19.87	19.50	21.29	22.24	21.77
Z_4F_3: Zeolite @ 50 kg ha^{-1} + 100% RDF	45.58	50.55	48.06	41.85	45.80	43.82	21.42	22.16	21.79	23.58	24.54	24.06
Z_4F_4: Zeolite @ 50 kg ha^{-1} + 125% RDF	48.08	52.63	50.36	44.22	49.11	46.66	21.97	22.71	22.34	24.13	25.09	24.61
S.Em±	**0.46**	**0.50**	**0.44**	**0.53**	**0.46**	**0.49**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**	**0.46**
CD (P=0.05)	**1.33**	**1.43**	**1.26**	**1.51**	**1.32**	**1.39**	**1.38**	**1.38**	**1.38**	**1.37**	**1.38**	**1.38**

Table.3 Soil microbial biomass carbon and nitrogen in soil at ear head and harvest stage of finger millet as influenced by different levels of zeolite and fertilizer application

Treatments	MBC (μg g^{-1}) At earhead stage			MBC (μg g^{-1}) Post-harvest soil			MBN (μg g^{-1}) At earhead stage			MBN (μg g^{-1}) Post-harvest soil		
	2017	2018	pooled	2017	2018	pooled	2017	2018	pooled	2017	2018	pooled
Zeolite levels												
Z_0 : Control	262.39	264.21	263.30	259.83	256.46	258.14	38.35	41.95	40.15	35.40	39.37	37.38
Z_1 : Zeolite @ 20 kg ha^{-1}	276.79	276.20	276.49	262.14	267.34	264.74	41.48	44.46	42.97	38.21	41.78	39.99
Z_2 : Zeolite @ 30 kg ha^{-1}	286.12	287.70	286.91	270.90	277.75	274.32	42.53	45.08	43.81	39.07	42.52	40.80
Z_3 : Zeolite @ 40 kg ha^{-1}	292.36	296.74	294.55	278.23	285.36	281.79	43.23	46.53	44.88	40.06	43.50	41.78
Z_4 : Zeolite @ 50 kg ha^{-1}	302.12	306.56	304.34	287.72	294.18	290.95	47.05	49.41	48.23	42.61	46.05	44.33
S.Em±	**9.93**	**11.35**	**10.01**	**9.33**	**9.33**	**9.33**	**3.11**	**3.06**	**3.08**	**3.12**	**3.12**	**3.12**
CD (P=0.05)	**29.70**	**34.02**	**30.01**	**NS**	**27.99**	**28.01**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
Fertilizer levels												
F_1: 50% RDF	267.39	274.66	271.03	260.52	264.78	262.65	37.74	40.42	39.08	33.85	37.51	35.68
F_2: 75% RDF	282.40	282.80	282.60	268.22	272.92	270.57	40.77	43.95	42.36	37.50	41.05	39.27
F_3: 100% RDF	290.28	290.68	290.48	275.76	280.36	278.06	44.51	47.90	46.21	41.27	44.82	43.05
F_4: 125% RDF	295.75	296.98	296.36	282.55	286.82	284.69	47.09	49.68	48.38	43.65	47.20	45.42
S.Em±	**8.88**	**10.16**	**8.96**	**8.34**	**8.34**	**8.34**	**2.78**	**2.74**	**2.75**	**2.79**	**2.79**	**2.79**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**8.34**	**8.22**	**8.25**	**8.37**	**8.37**	**8.37**
Zeolite levels X Fertilizer levels												
Z_0F_1: Control + 50% RDF	224.88	253.10	238.99	248.73	245.35	247.04	32.36	36.13	34.25	29.40	33.37	31.39
Z_0F_2: Control + 75% RDF	269.01	262.89	265.95	258.51	255.13	256.82	35.31	39.09	37.20	32.36	36.33	34.34
Z_0F_3: Control + 100% RDF	270.50	262.70	266.60	258.32	254.94	256.63	40.84	44.61	42.73	37.88	41.85	39.87
Z_0F_4: Control + 125% RDF	285.16	278.15	281.66	273.77	270.40	272.09	44.90	47.95	46.42	41.94	45.91	43.93
Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF	266.60	266.20	266.40	253.25	258.44	255.85	36.34	40.12	38.23	33.39	37.36	35.37
Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF	266.24	263.61	264.93	250.66	255.86	253.26	38.98	42.01	40.50	35.61	39.05	37.33
Z_1F_3: Zeolite @ 20 kg ha^{-1} +100% RDF	283.36	282.94	283.15	267.78	272.98	270.38	43.76	46.78	45.27	40.38	43.82	42.10

Z_1F_4: Zeolite @ 20 kg ha^{-1} +125% RDF	290.96	292.04	291.50	276.88	282.08	279.48	46.83	48.94	47.89	43.45	46.90	45.18
Z_2F_1: Zeolite @ 30 kg ha^{-1} + 50%RDF	272.19	271.76	271.97	256.61	261.80	259.21	37.60	40.19	38.89	34.22	37.67	35.95
Z_2F_2:Zeolite @ 30 kg ha^{-1} + 75% RDF	284.43	286.21	285.32	268.85	276.25	272.55	41.04	43.41	42.22	37.66	41.11	39.39
Z_2F_3:Zeolite @ 30 kg ha^{-1} + 100% RDF	291.17	292.95	292.06	275.59	282.99	279.29	44.77	47.84	46.30	41.23	44.68	42.96
Z_2F_4:Zeolite @ 30 kg ha^{-1} + 125% RDF	296.68	299.90	298.29	282.55	289.94	286.25	46.71	48.91	47.81	43.17	46.62	44.90
Z_3F_1: Zeolite @ 40 kg ha^{-1} + 50% RDF	284.52	289.16	286.84	270.38	277.78	274.08	38.82	41.88	40.35	35.28	38.72	37.00
Z_3F_2: Zeolite @ 40 kg ha^{-1} + 75% RDF	292.02	296.66	294.34	277.89	285.28	281.59	42.10	46.17	44.13	39.57	43.01	41.29
Z_3F_3: Zeolite @ 40 kg ha^{-1} + 100% RDF	299.98	304.10	302.04	285.84	292.72	289.28	44.63	48.74	46.68	42.14	45.58	43.86
Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF	292.93	297.05	294.99	278.79	285.67	282.23	47.38	49.34	48.36	43.24	46.68	44.96
Z_4F_1: Zeolite @ 50 kg ha^{-1} + 50% RDF	288.77	293.09	290.93	273.63	280.51	277.07	43.58	43.78	43.68	36.97	40.42	38.70
Z_4F_2: Zeolite @ 50 kg ha^{-1} + 75% RDF	300.31	304.63	302.47	285.18	292.05	288.61	46.42	49.09	47.75	42.28	45.73	44.01
Z_4F_3: Zeolite @ 50 kg ha^{-1} + 100% RDF	306.41	310.73	308.57	291.28	298.15	294.71	48.57	51.53	50.05	44.73	48.17	46.45
Z_4F_4: Zeolite @ 50 kg ha^{-1} + 125% RDF	313.00	317.78	315.39	300.77	305.99	303.38	49.62	53.24	51.43	46.44	49.88	48.16
S.Em±	**19.86**	**22.71**	**20.03**	**18.66**	**18.65**	**18.65**	**6.22**	**6.13**	**6.16**	**6.25**	**6.25**	**6.25**
CD (P=0.05)	**59.60**	**68.10**	**60.04**	**55.95**	**55.91**	**55.93**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Table.4 Soil microbial phosphorus in soil at ear head and harvest stage of finger millet as influenced by different levels of zeolite and fertilizer application

Treatments	MBP (µg g^{-1}) At earhead stage			MBP (µg g^{-1}) Post-harvest soil		
	2017	2018	pooled	2017	2018	pooled
Zeolite levels						
Z_0 : Control	36.10	34.45	35.28	38.27	36.83	37.55
Z_1 : Zeolite @ 20 kg ha^{-1}	38.80	37.25	38.03	40.90	39.93	40.42
Z_2 : Zeolite @ 30 kg ha^{-1}	40.15	39.44	39.80	42.73	42.32	42.52
Z_3 : Zeolite @ 40 kg ha^{-1}	40.48	41.25	40.87	43.60	44.31	43.96
Z_4 : Zeolite @ 50 kg ha^{-1}	44.25	43.28	43.77	47.14	46.62	46.88
S.Em±	**3.11**	**2.78**	**2.92**	**2.90**	**2.78**	**2.81**
CD (P=0.05)	**NS**	**8.34**	**8.76**	**8.72**	**8.34**	**8.42**
Fertilizer levels						
F_1: 50% RDF	35.15	34.60	34.88	38.36	37.37	37.86
F_2: 75% RDF	38.18	37.94	38.06	41.33	40.79	41.06
F_3: 100% RDF	41.92	40.73	41.32	44.41	43.61	44.01
F_4: 125% RDF	44.59	43.27	43.93	46.01	46.23	46.12
S.Em±	**2.78**	**2.49**	**2.62**	**2.59**	**2.49**	**2.52**
CD (P=0.05)	**8.34**	**7.46**	**7.85**	**7.75**	**7.47**	**7.56**
Zeolite levels X Fertilizer levels						
Z_0F_1: Control + 50% RDF	29.99	29.94	29.97	32.75	32.32	32.53
Z_0F_2: Control + 75% RDF	32.95	32.51	32.73	35.70	34.88	35.29
Z_0F_3: Control + 100% RDF	38.47	35.22	36.85	41.23	37.60	39.41
Z_0F_4: Control + 125% RDF	43.00	40.15	41.58	43.39	42.52	42.96
Z_1F_1: Zeolite @ 20 kg ha^{-1}+ 50% RDF	33.67	30.99	32.33	36.64	33.37	35.01
Z_1F_2: Zeolite @ 20 kg ha^{-1}+ 75% RDF	36.31	35.85	36.08	39.28	38.62	38.95
Z_1F_3: Zeolite @ 20 kg ha^{-1} +100% RDF	41.08	39.89	40.49	42.93	42.66	42.80
Z_1F_4: Zeolite @ 20 kg ha^{-1} +125% RDF	44.15	42.28	43.22	44.76	45.05	44.90
Z_2F_1: Zeolite @ 30 kg ha^{-1} + 50%RDF	35.22	34.13	34.67	38.74	36.90	37.82
Z_2F_2:Zeolite @ 30 kg ha^{-1} + 75% RDF	38.66	38.22	38.44	42.18	40.99	41.58
Z_2F_3:Zeolite @ 30 kg ha^{-1} + 100% RDF	42.39	41.79	42.09	43.71	44.77	44.24
Z_2F_4:Zeolite @ 30 kg ha^{-1} + 125% RDF	44.33	43.63	43.98	46.29	46.61	46.45
Z_3F_1: Zeolite @ 40 kg ha^{-1} + 50% RDF	36.07	37.93	37.00	39.47	40.91	40.19
Z_3F_2: Zeolite @ 40 kg ha^{-1} + 75% RDF	39.35	40.10	39.73	42.75	43.08	42.91
Z_3F_3: Zeolite @ 40 kg ha^{-1} + 100% RDF	41.88	42.36	42.12	45.28	45.34	45.31
Z_3F_4: Zeolite @ 40 kg ha^{-1} + 125% RDF	44.63	44.59	44.61	46.89	47.93	47.41
Z_4F_1: Zeolite @ 50 kg ha^{-1} + 50% RDF	40.79	40.03	40.41	44.18	43.37	43.78
Z_4F_2: Zeolite @ 50 kg ha^{-1} + 75% RDF	43.62	43.03	43.33	46.76	46.36	46.56
Z_4F_3: Zeolite @ 50 kg ha^{-1} + 100% RDF	45.78	44.37	45.07	48.91	47.70	48.31
Z_4F_4: Zeolite @ 50 kg ha^{-1} + 125% RDF	46.83	45.69	46.26	48.72	49.03	48.87
S.Em±	6.22	5.56	5.85	5.80	5.56	5.63
CD (P=0.05)	18.66	16.66	17.53	17.40	16.64	16.89

The phosphatase activity was maximum due to use of zeolite as compared to chemical fertilizers, since zeolite has water holding capacity and releases the nutrients slowly, that might have enhanced the acid phosphatase activity. These results are in conformity with the findings of Sriramachandrasekharan and Mathan (1997).

Application of FYM along with zeolite and fertilizers into the soil pool which leads to mineralization over the period of time has supplied carbon which served as energy source for the P solubilizers in organics. The results could also be attributed to the more soil P which served more proliferation of P solubilizers in the finger millet crop.

The increased enzyme activities in organically amended soils are generally attributed to the increased inputs of organic substrates which stimulate microbial growth and enzyme synthesis (Dick, 1992). Results can be correlated with Kaur and Reddy (2014) in their studies using PSB for maize crop yield.

Alkaline phosphatase activity at ear head stage and after harvest of the crop

Data pertaining to alkaline phosphatase as influenced by application of different levels of fertilizer and zeolite have been presented in Table 2.

The use of zeolite at various levels showed significant differences in alkaline phosphatase activity at earhead stage and after harvest of the crop. At earhead stage of the crop, the alkaline phosphatase activity significantly higher in treatment received 50 kg ha^{-1} zeolite (Z_4), 19.77 µg PNP g^{-1} h^{-1}, 20.51 µg PNP g^{-1} h^{-1} and 20.14 µg PNP g^{-1} h^{-1} when compared to control which received no zeolite (Z_0), 15.42 µg PNP g^{-1} h^{-1}, 16.00 µg PNP g^{-1} h^{-1} and 15.71 µg PNP g^{-1} h^{-1} in first, second season and pooled data, respectively.

In post-harvest soils, the alkaline phosphatase activity significantly higher in treatment received 50 kg ha^{-1} zeolite (Z_4), 21.93 µg PNP g^{-1} h^{-1}, 22.88 µg PNP g^{-1} h^{-1} and 22.40 µg PNP g^{-1} h^{-1} when compared to control which received no zeolite (Z_0), 17.40 µg PNP g^{-1} h^{-1}, 18.16 µg PNP g^{-1} h^{-1} and 17.78 µg PNP g^{-1} h^{-1} during first, second season and pooled data, respectively.

At earhead stage of the crop, significantly higher alkaline phosphatase activity was recorded in treatment F_4 (125% RDF) 19.17 µg PNP g^{-1} h^{-1}, 19.87 µg PNP g^{-1} h^{-1} and 19.52 µg PNP g^{-1} h^{-1} during first, second season and pooled data, respectively fallowed by treatment F_3 (100% RDF) (18.32 µg PNP g^{-1} h^{-1}, 19.01 µg PNP g^{-1} h^{-1} and 18.67 µg PNP g^{-1} h^{-1}), The lower alkaline phosphatase activity was recorded in the treatment which received 50 per cent RDF (F_1) (15.23 µg PNP g^{-1} h^{-1}, 15.92 µg PNP g^{-1} h^{-1} and 15.57 µg PNP g^{-1} h^{-1}) during first, second season and pooled data, respectively. in post-harvest soil, significantly higher alkaline phosphatase activity was recorded in treatment F_4 (125% RDF) 21.15 µg PNP g^{-1} h^{-1}, 22.12 µg PNP g^{-1} h^{-1} and 21.63 µg PNP g^{-1} h^{-1} during first, second season and pooled data, respectively.

The lower alkaline phosphatase activity was recorded in the treatment which received 50 per cent RDF (F_1) (17.20 µg PNP g^{-1} h^{-1}, 18.13 µg PNP g^{-1} h^{-1} and 17.67 µg PNP g^{-1} h^{-1}) during first, second season and pooled data, respectively. Pooled data of two years (2017 and 2018) revealed significant difference in alkaline phosphatase activity was observed due to interaction of zeolite and fertilizer levels at earhead stage of the crop. The treatment which received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) showed higher alkaline phosphatase activity (21.97 µg PNP g^{-1} h^{-1}, 22.71 µg PNP g^{-1} h^{-1} and 22.34 µg PNP g^{-1} h^{-1}) followed by treatment received zeolite 50 kg ha^{-1} +100 per cent RDF (Z_4F_3) (21.42 µg PNP g^{-1} h^{-1}, 22.16 µg PNP g^{-1} h^{-1} and 21.79 µg PNP g^{-1}

h^{-1}) during first, second season and pooled data, respectively.

Whereas, lower alkaline phosphatase activity was recorded in the treatment which received 50 per cent RDF with no zeolite (Z_0F_1) (13.82 µg PNP g^{-1} h^{-1}, 14.40 µg PNP g^{-1} h^{-1} and 14.11 µg PNP g^{-1} h^{-1}).

Pooled analysis of two years of experimental data (2017 and 2018) revealed that a significant difference in alkaline phosphatase activity was observed in post-harvest soils due to interaction of zeolite and fertilizer levels with higher activity in Z4F4 (24.13, 25.09 and 24.61 µg PNP g^{-1} h^{-1}) and lower activity in Z_0F_1 (15.80, 16.55 and 16.18 µg PNP g^{-1} h^{-1}).

Since, soil pH was acidic, the alkaline phosphatase activity found lower in the present study. Chemical fertilizers have bit decreased the soil pH and leads to acidic.

Alkaline phosphatase activity found higher in the treatment received zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4) and zeolite 50 kg ha^{-1} +125 per cent RDF (Z_4F_4), this might be due to harmless nature of zeolite to the microbial load intern nutrient application leads to the sufficient nutrient supply to microbes for their growth and development.

Application of FYM as recommended in the package of practice also contributed for the development of microbes.

Microbial biomass carbon (MBC), Microbial biomass nitrogen (MBN) and Microbial biomass phosphorus (MBP) at ear head stage and after harvest of the crop

Data pertaining to soil MBC, MBN and MBP at earhead stage and after harvest of finger millet crop as influenced by application of different levels of fertilizer and zeolite has been presented in Table 3 and 4.

The pooled data of MBC at earhead stage and post-harvest soil varied significantly due to different levels with higher MBC of 304.34 and 290.95 µg g^{-1}, respectively which were significant with Z_0 (263.30 and 258.14 µg g^{-1}). In fertilizers levels, the MBC at earhead and post-harvest soil did not varied significantly. But higher values were seen in F_4 (296.36 and 284.69 µg g^{-1}).

In the interaction treatments, MBC varied significant at both earhead and post-harvest soil with higher value of 315.39 and 303.38 µg g^{-1}, respectively which were significant with Z_0F_1 (238.99 and 247.04 µg g^{-1}) and on par with rest of the treatments.

The MBN at earhead and post-harvest soil varied significantly with different fertilizers but non-significant with zeolite levels and the interactions. With respect to fertilizer levels, significantly higher MBN was seen in F_4 (48.38 and 45.42 µg g^{-1}) which was on par with all the treatments except F_1 (39.08 and 35.68 µg g^{-1}).

Table 4 indicated the soil microbial biomass Phosphorus at earhead and post-harvest stage as influenced by zeolite and fertilizer levels. The MBP at ear head stage and post-harvest soil varied significantly with higher MBC of 43.77 and 46.88 µg g^{-1} at earhad and post-harvest stage, respectively in Z_4 (zeolite @ 50 kg ha^{-1}) which were significantly higher than Z_0 (35.28 and 37.55 µg g^{-1}, respectively). In different fertilizer levels also MBP varied significantly with higher MBP of 43.93 and 46.12 µg g^{-1} in F_4 (125% RDF).

Zeolites are hydrated crystalline aluminosilicates, naturally occurring mineral having the favorable properties required for the better crop growth by making higher availability of nutrients and water for longer period. Zeolite application @ 50 kg ha^{-1} along with 100% and 125% RDF showed higher dehydrogenase, urease and phosphatase activity compared to other treatments. The above study clearly emphasis the goodness of zeolite inclusion in nutrient management practices and its influence on microbial activity in the soil.

References

Ajay, B., Jatav, H. S., Maneesh, V. and Seema., 2017, Effect of FYM and inorganic fertilizer on soil microbial biomass and enzyme activities of Indo-Gangetic plains, Varanasi, India. *Int. J. Curr. Microbiol. App. Sci.*, 6(2):559-565.

Amanda Shylla, 2012, Microbial and biochemical soil health indicators for dry land agriculture in alfisols. *M.Sc. (Agri.) Thesis*, *Univ. Agril. Sci.*, Bengaluru, India.

Burriesci, N., Valente, S., Ottanà, R., Cimino, G. and Zipelli, C., 1984, Utilization of zeolites in spinach growing. *Zeolites*. 4:5–8.

Carter, M. R., 1991, Ninhydrin-reactive N released by the fumigation extraction method as a measure of microbial biomass under field conditions. *Soil Biol*. *Biochem.*, 23:139-143.

Casida, L.E., Jr., Klein, D.A. and Santoro, T., 1964, Soil dehydrogenase activity. *Soil Sci*., 98:371.

Chakrabarti, K., Sarkar, B., Chakrabarty, A., Banik, P. and Bagchi, D. K., 2000, Organic recycling for soil quality conservation in a sub-tropical plateau region. *J. Agron. Crop Sci.*, 184:137-142.

Diaz-Marcote, I. and Polo, A., 1995: MSW compost for the restoration of degraded soil. In World Congress on Waste Management. Proc. of the 25th Anniversary of the International Solid Waste Association. 15th-20th October, 1995 ISWA, Vienna (CD Rom).

Dick, R.P., 1992, A review: Long-term effects of agricultural systems on soil biochemical and microbial parameters. Agric. Ecosyst. Environ., 4:25-36.

Dilly, O., Munch, J. C. and Pfeiffer, E. M., 2007, Enzyme activities and litter decomposition in agricultural soils in northern, central and southern Germany. *J. Plant. Nutr. Soil Sci*., 170:197-204.

Kaur G, M. and Reddy, S., 2014, Influence of P-solubilizing bacteria on crop yield and soil fertility at multilocational sites, *European J. Soil Bio*.61: 35-40.

Mohammadi K, Heidari G, Nezhad MTK, Ghamari S, Sohrabi Y., 2012, Contrasting soil microbial responses to fertilization and tillage systems in canola rhizosphere. Saudi J Biol. Sci. 19(3): 377-383.

Mumpton, F. A., 1999, La Roca Magica: uses of natural zeolites in agriculture and industry. Proc. Natl. Acad. Sci. USA. 96:3463–3470. doi:10.1073/pnas.96.7.3463.

Navrotsky, A., Petrovic, I., Hu, Y., Chen, C. Y. and Davis, M. E., 1995, Energetics of microporous materials. *J. Noncrystalline Solids*. 19:474–477.

Olsen, S. R., Cole, C. V., Watanabe, F. S. and Dean. L. A., 1954. Estimation of available phosphorus in soils by extraction with NaHCO3, USDA Cir.939. U.S. Washington.

Perez-DE-Mora A. and Madrid, C. F., 2007, Amendments and plant cover influence on trace elements pools in a contaminated soil. *Geoderma*., 139: 1.

Perucci, P., 1990, Effect of the addition of municipal solid-waste compost on microbial biomass and enzyme activities in soil. *Biol. Fert. Soils*, 10: 221-226.

Rochette, P.; Angers, D. A. and Flanagan, L.B., 1999, Maize residue decomposition measurement using soil surface carbon dioxide fluxes and natural abundance of carbon-13. Soil Sci. Soc. Am. J., 63:1385–1396.

Sriramachandrasekharan M.V., Mathan KK. 1997, Influence of zinc sources on the yield components, dry matter production and yield of rice. *Madras Agric. J*, 75: 200-203.

Tabatabai M. A. 1994, Soil enzymes. Amer. Soc. Agron., 14:77.

Tabatabai, M. A. and J.M. Bremner. 1972. Assay of urease activity in soil. *Soil Biol. Biochem*., 4: 479-487.

Vasseur, C., Joannon, A., Aviron, S.; Burel, F., Meynard, J.M., Baudry, J. 2013, The cropping systems mosaic: How does the hidden heterogeneity of agricultural landscapes drive arthropod populations? *Agric. Ecosyst. Environ* 166:3–14.

Wang, B., Xue, S., Liu, G. B., Zhang, G. H, Li, G. and Ren, Z. P., 2012, Changes in soil nutrient and enzyme activities under different vegetations in the Loess Plateau area, Northwest China. *Catena*., 92:186–195.

Widmer, F., Rasche, F., Hartmann, M. and Fliessbach, A., 2006, Community structures and substrate utilization of bacteria in soils from organic and conventional farming system of the DOK long-term field experiment. *Appl. Soil Ecol*., 33:294.

Wyszkowska, J., Kucharski, M., Kucharski, J. and Borowik, A., 2009 Activity of dehydrogenases, catalase and urease in copper polluted soil. *J. Elementol*. 14(3): 605.

Xiubin, H. and Zhanbin, H., 2001, Zeolite application for enhancing water infiltration and retention in loess soil. *Conserv Recyling*. 34:45–52.

Yapparov-FSH, Shilovskii, LP, Tsitsishvili, G. V. and Ronikashvili, T. G., 1988, Growing certain vegetables on substrates containing natural zeolites. *Hort. Abstr*. 2:117–121.

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